Our Choices Have International Side Effects: A Look at Climate Change

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Abstract

Climate change has become a household term, a growing issue that is affecting people and animals alike. An ever changing climate is the result of the Earth's rotation around the sun, an activity that causes natural heating and cooling cycles. There is cause to believe that human activities have worsened the severity of climate change, and we are currently seeing a rise in the average land and sea temperatures. Climate change and its sources cause varying issues for human health, economy, and fragile ecological communities. While spending a semester in Australia, home of the Great Barrier Reef, I analyzed climate change and its effects on coral reefs.

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Introduction

Climate change and global warming are a big deal in today's political agenda with varying statements and arguments about whether climate change is occurring, whether it is the result of falsified data from bias scientists, and whether or not we should be concerned about the potential effects of a slowly changing climate[1, 2, 3]. The bottom line is that climate change is indeed occurring; a natural cycle caused by the rotation around the sun[4]. Whether or not the change in the present cycle is worse due to anthropogenic human-related consequences is still being debated at many research facilities around the world. This debate can be confusing for a layperson of the general public trying to discern whether climate change is a legitimate problem that needs to be faced or if the concern can remain on the back burner.

In addition, different areas of the world perceive climate change differently, and understandably so. Places that experience unusual weather may perceive the severity of climate change as greater than an area experiencing familiar weather patterns. This past year, both the United States and Australia experienced atypical weather[5]. Both have experienced record breaking temperature highs[6, 7], as well as hurricanes or cyclones in areas that typically are not affected by such weather. How each of the two countries perceives the effects of climate change are vastly different, and as such they both have different stances on the potential severity should regulations and policies remain unchanged.

The Changing Climate

Climate Change versus Global Warming

First, it is important to define what is meant by climate change and global warming and to acknowledge that many people use the terms interchangeably. Climate change is what it

sounds like: an overall change in climate, including changes in both precipitation and temperature. In recent years the term has been increasingly used in the United States because of record-breaking weather patterns. Global warming generally refers to only one aspect of climate change, an overall increase in the average temperature of the Earth's surface[8].

To many who are unfamiliar with what is meant by global warming, it could appear to not exist. Places still experience cold weather, record low temperatures, and massive snow storms, so many come to the conclusion that global warming is just a hoax created by environmentalists with an agenda[3]. What is truly meant by the term "global warming" is a subtle increase in average temperature across the globe, marked by changes in both sea and land temperatures.

Measurements are Rising

Everyday thousands of measurements are taken around the globe, including various surface measurements from climate reference stations, weather stations, ships, and ocean buoys monitored by NASA Goddard Institute for Space Studies, Met Office Hadley Centre/Climatic Research Unit, NOAA National Climatic Data Center, and the Japanese Meteorological Agency amongst others (Figure 1)[9]. These are supplemented with satellite measurements and then processed and examined for errors. The information is combined to obtain global average temperatures. With the graphs that are produced, the increase or decrease in overall temperature over time becomes visible. The National Climatic Data Center (NCDC), which operates through the National Oceanic and Atmospheric Administration (NOAA), states that:

> "A number of agencies around the world have produced datasets of global-scale changes in surface temperature using different techniques to process the data and remove

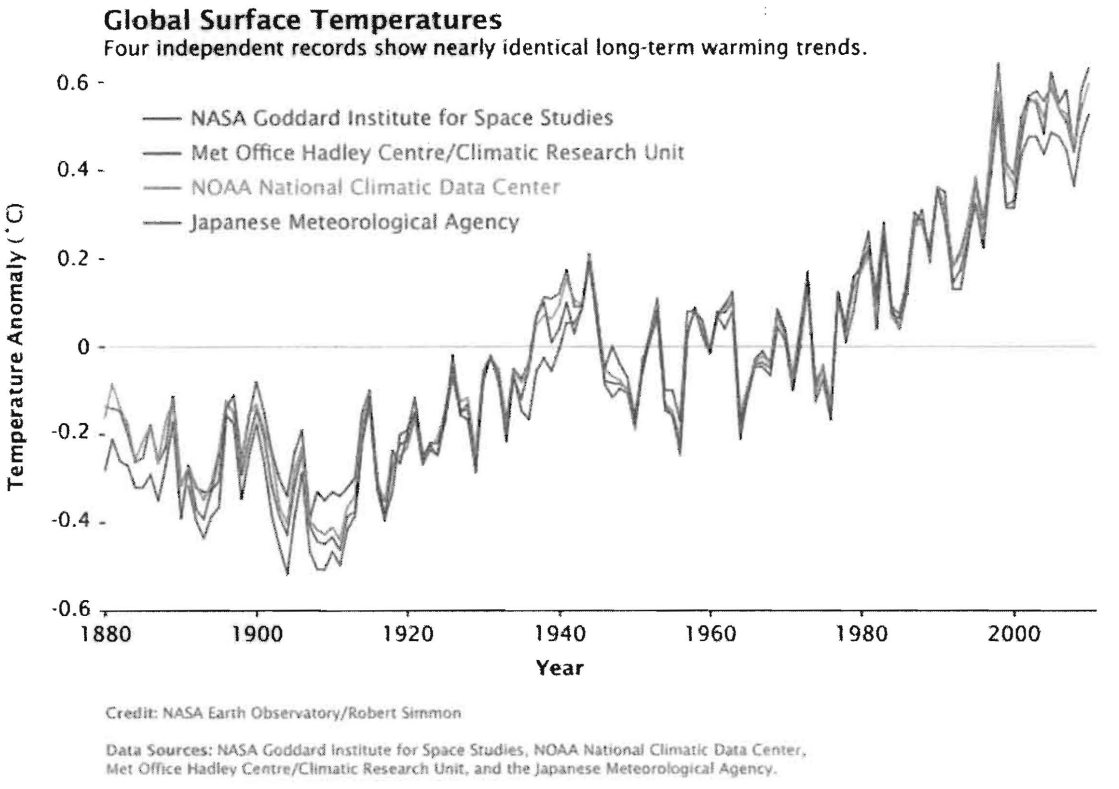

Figure 1

measurement errors that could lead to false interpretations of temperature trends. The warming trend that is apparent in all of the independent methods of calculating global temperature change is also confirmed by other independent observations…"[9]

The other observations that they suggest are a decrease in glacial volume combined with rising ocean temperatures and sea level, a reduction in mountain glaciers and snow cover, and overall shorter winter seasons.

Surface temperature measurements over the past 130 years have indicated a change in surface temperature of approximately 1.4°F, with the 20 warmest years occurring since 1981, and the 10 warmest occurring in the last 12 years. The sea level is also rising, as noted and observed through tidal gauges. Over the past 100 years, the sea level has risen an average of 1.7 mm per year, accelerating to 3.5 mm per year within the last 20 years[9]. This means that not only

are the sea levels continuing to rise, but they are doing so at an accelerating rate. It is predicted that as land ice begins to melt, it will have a significant impact on sea level. Despite the scientific communities claim that these numbers are significant[9], such small numbers could cause skepticism amongst the public.

These trends we are experiencing, such as increased temperature and short winters, can be argued to be part of a natural cycle that we do not have to be concerned about. Though it has been confirmed that the Earth has cycled through similar trends, it is not without concern. A changing climate can cause a myriad of other changes[10, 11]. Previous cycles have been faced by a much less populated Earth. Our increased population means a considerably greater number of people will be affected should the changing climate affect crops or other parts of the food industry. Increased ocean temperatures can have a significant impact on hurricane and cyclone patterns[12], affecting coastal tourism and marine resource industries. Higher land temperatures can also affect overall weather patterns with a high probability of increased severe weather, including tornadoes and drought for the United States.

What Causes Climate Change?

The overall consensus is that climate change is sparked by increasing temperatures caused by more solar radiation being trapped in Earth's atmosphere. This is the result of a buildup of greenhouse gases, most notably carbon dioxide, but also sulfur dioxide, methane, nitrous oxide, hydrofluorocarbons, ozone, and even water vapor. These gases absorb solar radiation that would otherwise be lost to space. In this way, the buildup of gases acts like a blanket, retaining heat against the Earth's surface. This is known as the greenhouse effect[13, 14].

A number of natural occurrences can contribute to climate change by shifting the intensity of solar radiation, including minute changes in the Earth's tilt over thousands of years, solar activity that increases or decreases the intensity of solar radiation being absorbed or reflected by the atmosphere, seasonal changes that result in the release of carbon dioxide, and volcanic activity that increases greenhouse gases[13]. These natural causes are few and far between, which means that, though they do have an effect, it is generally not significant or occurring over the span of thousands of years.

Humans may be having a large impact on climate change. Though the Earth cycles through heating and cooling patterns, data suggest that human impact has caused the Earth to heat up at an accelerated rate. The Intergovernmental Panel on Climate Change (IPCC) has concluded that there is a near 90 percent probability that human activities over the past 250 years has contributed to heating the planet[14]. To curb the effect of humans on climate change, we all need to take responsibility for our actions. Greater awareness is needed of the goods that are consumed and what goes into making these goods. There also needs to be an effort by companies and businesses when it comes to the turnover of their products and the way they are disposed of or recycled.

Increase in Consumerism a Factor

An increasing world population may be a contributing factor in global warming. Increased population implies more vehicles, an increase in generated electricity, a need for the clearing of land, and an increased production of goods. All of these services produce waste in the form of gases, and the clearing of land (i.e., deforestation) prevents the absorption of carbon dioxide by trees and other plants. Our vehicles and factories produce carbon dioxide, methane,

nitrous oxide, and hydrofluorocarbons[15, 16]. Even with regulations in place there is an issue with the amount of greenhouse gases released. There are simply too many people requesting goods and services.

In many ways our problems with climate change can be linked to our desire for goods and services beyond those needed for survival. Our culture often has the expectation that individuals should always have the newest technology and be up to date with the newest equipment and hardware. Though this can be beneficial, such as cars with better emission ratings and new fuel technology, it also means that there is a high turnover rate for many technological goods. All of these goods are made through a web of processes that produce waste, which causes greater pollution problems than just global warming, and release gases that contribute to the greenhouse effect. Cell phones are a big factor. Many service contracts allow a product turnover of 2 years, meaning that many people are replacing their cell phones every 2 years or less. A large amount of pollution and greenhouse gases are produced through the manufacturing process for the product to only be used for a few years.

Currently, the poorest nations are being affected by climate change rather than effecting it[17]. As developing nations move up in the economic world, there is an even higher demand for these goods. Though it seems just for every nation to be capable of aspiring to have a stable economy, it is questionable whether that goal is sustainable. A larger economy is often accompanied by an increased desire for luxury items. As nations gain wealth, they also start to slowly implement technologies before they have the means to provide proper regulatory systems. Development is a balancing act that aims at providing a country's citizens with a decent standard of living without establishing systems that will only need to be replaced later in development. Poor countries cannot be expected to be able to afford the newest technologies that aim at

producing the lowest amount of pollution possible. Climate change is a worldwide problem that can only be solved by every nation working together. Development occurs in the same pattern for all countries, the key is to find ways to help the developing world bypass dirty industries without compromising their development.

Effects of Climate Change

Effect on Humans

Climate change has brought about severe, and possibly permanent, alterations to Earth's geological, biological, and ecological systems. These changes have led to the emergence of large-scale environmental hazards to human health, such as ozone depletion, loss of biodiversity, stresses on food-producing systems, and the global spread of infectious diseases[18]. These changes can bring about heat-related illness and death, and air pollution-related death, including impacts on ground ozone, malnutrition, and storm surge-related accidents. The World Health Organization (WHO) estimates that 160,000 deaths since 1950 are directly attributable to climate change[19].

The biggest concern for humans should be the effect on water quality, its scarcity, and food production. These systems are already delicate with problems worldwide. Isolated cases of water scarcity are already being seen with increasing populations. The Colorado River was diverted to supply Los Angeles, Las Vegas, and the surrounding areas – this action has left the Colorado River's delta dry, and the river rarely reaches past the Mexican border and into the sea[20]. If there is an extensive drought, the west coast of the United States could experience an issue with water scarcity that would affect some of the most populated cities. Winter droughts are also impacting rivers during the spring season. Some locations rely on spring runoff from

melting snow to replenish local water supplies. A loss of crops due to drought would be devastating, not only for the direct consumption of crop foods, but also for secondary consumption. Many crops are used to feed cattle and produce other goods. If corn is specifically affected, we would see a severe increase in nearly all food prices, as corn meal and corn syrup are major components in a lot of food products. This could also have a potential effect on exports and trade, potentially having negative consequences on local and national economics.

Economies around the world may also be impacted by the effect of weather changes on certain tourist industries, including coastal and mountain snow-based activities. Many places are experiencing record lows for winter precipitation and short winters, which are affecting all 103 ski locations across the east coast[21]. In the past decade, the $12.2 billion winter tourism industry has seen a $1 billion loss. It has also lost 27,000 jobs[22]. Small businesses in particular are being affected, as they cannot keep up with the costs and changes; many small ski slopes are selling out to large corporate businesses.

Diseases are another concern. Many widespread diseases, including malaria, dengue fever, and cholera, are climate sensitive – this is in part to the diseases being transmitted by mosquitoes, which need accumulated water to reproduce and cannot survive in low temperatures. How climate change will affect the spread of disease is hard to predict. Changes in temperature and precipitation mean changes in the timing, location, and intensity of disease outbreaks. Consequences have already been seen in isolated areas. In 2000, Mozambique experienced three cyclones in a 6-month period, which resulted in flooding and a spike in malaria cases[23]. Even if the effect is the opposite and the area experiences unusual dryness, over time the population may leave the area and move into areas where disease vectors are prevalent.

Humans also have to deal with a loss of ozone, which means an increase in the penetration of ultraviolet (UV) light. This loss is caused by the reaction of various industrial chemicals that destroy atmospheric ozone. Increased UV light is a significant cause of increasing malignant skin cancer rates, as well as other bodily consequences. The eyes and skin are the most sensitive to UV radiation, with the eyes becoming susceptible to cancer of the cornea and conjunctiva, cataracts, and macular degeneration[24]. These health effects as a consequence of climate change can, in turn, affect health insurance policies that already being affected by current economic issues.

Australia and New Zealand currently have the highest incidences of skin cancer. Here you will find publically funded commercials promoting proper skin care, including covering up skin when outside and applying plentiful sunscreen use[25]. While studying for a semester it became obvious that many schools, ranging from primary to university, encouraged and expected students to wear sleeved shirts and hats when participating in organized activities outside.

Effect on Wildlife – An in-depth look at Corals

Some of the effects of climate change on wildlife are similar to the effects on humans, but wildlife and plants are also affected in ways that we are not. Many organisms rely on climate consistency to time biological processes. As weather patterns become atypical, the distribution and behavior of plants and animals can change. Most often these changes involve distribution ranges and migratory patterns. These changes can go on to affect niches, animal territories, and have serious overall consequences for sensitive ecological communities. One of the reasons that the effects are so strong is because ecological communities are dealing with other stresses as well. In addition to climate change, these systems are dealing with dwindling water supplies,

smaller habitats, and increased pollution from expanding populations. Some organisms are very sensitive to change, climate-related or otherwise. If these species experience too much damage, the effects are irreversible.

Corals are one of the many organisms affected by climate change. Corals are classified under the phylum cnidaria within the animal kingdom. The phylum is comprised of animals that use specialized cells called cnidocytes to capture their prey. The subphylum anthozoa includes corals, anemones, and sea pens. Anthozoans, unlike many other cnidarians, lack a medusa stage of development and instead release sperm and eggs for reproduction. The medusa is a free swimming organism, often with an umbrella shaped body. As an anthozoan, corals are strictly polyps and lack any free swimming stage of development. This means corals cannot migrate – any change in habitat would require the growth and formation of a new community.

What many people consider to be coral is compiled layers of calcium carbonate. This hard structure is excreted by communities of softer bodied polyps (coral polyps) that end up living at the head of the column of excreted calcium carbonate. These particular corals are the hard corals, made up of the excreted exoskeleton. Soft corals, such as sea whips, do not have this hard outer layer and appear plant like. Some people confuse these soft corals to be plants, possibly because they appear feathery and plant like and are only found within the photic zone. However, corals are a large multi-organism community. Because they are not plants, they cannot photosynthesize or produce their own food. Instead, corals rely on their symbiotic relationship with zooxanthellae for nutrients. Zooxanthellae are single-celled algae that live in the polyp's tissues providing nutrients and removing wastes. It is these reef-building organisms that restrict corals to the photic zone, the area of water within the range of sunlight. The mass amounts and various types of zooxanthellae are responsible for the variation of colors seen on coral reefs[26].

Coral reefs develop in tropical marine environments where there are very few seasonal changes in sunlight, water temperature, or nutrient levels. In these areas a thermocline is typically present, locking nutrients out of the surface water. This separation, nutrients in the lower cooler water with no nutrients in the surface area, restricts the growth of plants that could take over the corals ecological niche. There are more coral species in the Pacific Ocean than anywhere else in the world.

There are three types of reefs: fringing, barrier, and atoll. The differences rely on reef location and how it was formed. Fringing reefs are distinguished by having either a very shallow lagoon or none at all. Barrier reefs are formed as land sinks, leaving a deep lagoon and often causing them to be much farther from land than fringing reefs. Atolls are reefs that are annular reefs with a typically buried volcanic[27].

Classic reef formation starts as an island and gradually changes through millennia from a fringing reef, to a barrier reef, to an atoll. Fringing reefs form along the shoreline of new islands, which is why they are distinguished with little to no lagoon. As the island begins to sink, water fills the gap between the forming reef and the island forming a barrier reef. An atoll forms once the land mass sinks below the water's surface.

Coral relies heavily on multiple biological processes for its survival. Symbiosis is one of these processes, defined by two or more organisms living in close physical association with each other and typically benefitting from the situation. Already mentioned is coral's symbiotic relationship with zooxanthellae. In this relationship, the coral provides shelter to the zooxanthellae while the zooxanthellae provides to coral with nutrients and waste removal. Another example of a symbiotic relationship seen within a reef is the clown fish and the sea anemone. The anemone protects the clownfish from potential prey, and the clownfish helps

circulate water and clean the anemone. There are many other symbiotic relationships that can be seen on a reef, increasing reef vitality and allowing for the great biodiversity that can be seen. Reefs are easily affected by surrounding species. With increasing sea temperatures, reefs risk losing diversity of fish species which will migrate to more suitable water. It can also create favorable conditions for macro-algae, a significant predator to corals[28,29].

Limiting Factors and Threats to Corals

Corals are very sensitive organisms that are controlled by temperature, salinity, light, sedimentation, and nutrient levels. These restrictions limit coral reefs to very specific areas, typically around or off of islands within the tropics and subtropics. Corals cannot survive long periods in water temperature below 18°C, preferring water between 23°-29°C. Some can tolerate temperatures as high as 40°C for short periods, but high temperatures for long periods will kill coral polyps. Corals also require a high salinity, ranging from 32-42 parts per thousand, and low nutrient levels. Low nutrient levels result in clear water, as long as sedimentation is also low, allowing maximum light penetration[30].

Changes to the acceptable ranges to these restrictions often means death to the coral, or coral bleaching, named because the coral turns white/grey once the coral polyps have died and left behind their exoskeletons. Coral bleaching has increased in occurrences within the past twenty years, with most recent degradation seemingly related to anthropogenic impacts. These impacts include overexploitation, overfishing, nutrient overloading, and increased sedimentation[31]. While coral bleaching is a common stress response, there is concern that the widespread bleaching can be linked with other global changes such as global warming and ozone depletion.

A significant anthropogenic threat to coral reefs is run-off. Land based run-off can bring not only high sedimentation, blocking needed sunlight, but also other chemicals and nutrients that can promote algae growth that can smother a coral. Outside of run-off, human often consume goods that destroy reefs. This can include ornamental fish, popular for salt-water fish tanks, or fish that have been fished via trawling, a fishing technique that involves dragging nets across the ocean floor. Because anthropogenic threats often occur frequently over a long period of time, coral cannot easily recuperate from the trauma.

Natural disturbances are often more easily overcome by coral. These can include storms, changes in tide, and abnormal weather. Any of these occurrences can damage the coral, but the occurrences often take place over a relatively short period of time. These short occurrences allow the coral a period of regrowth and a chance to reestablish themselves after minor destruction. Even so, slow growing corals may be overcome by rapid growing algae that blocks needed light when in high concentrations.

Disease is another threat to corals, and is generally a response to stresses. This can include bacteria, viruses, and fungus, as well as increased temperature, ultraviolet radiation, and increased pollutants. Over the last ten years there has been a significant increase in the frequency of coral diseases. It is believed that this increase is caused by the deterioration of water quality, often related to anthropogenic pollutants. Excess nutrients, often found in pollutants, and increased sea temperatures create prime environments for the proliferation of microbes. The overall effect of these diseases is a loss of living tissue and exposure of skeleton. This exposed skeleton is fertile breeding grounds for algae and invertebrates which, once established, can deteriorate the health of the entire reef beyond recovery[26].

The Value of Coral Reefs

From a biological standpoint, coral reefs are one of the richest ecosystems in the world, containing roughly one third of marine biodiversity[32]. They are often considered the marine equivalent of terrestrial rainforests, supporting roughly 4,000 species of fish and 800 species of hard corals[33]. High diversity means a greater productivity and, in the case of reefs, a greater chance of surviving mass bleaching. This is because multiple species occupy similar niches on the reef, allowing ecological gaps to be filled should a species be affected by disease, predation or other stresses. Coral reefs also provide value to coastal communities by providing a buffer from wave action, offering some protection to the coast line often at the cost of the reef.

Coral reefs also hold value socially and economically. The high diversity found in coral reefs is an important aspect of medicines for the 21st century, benefiting economies and social wellbeing. A variety of drugs are currently being developed as possible cures for ailments such as arthritis, bacterial infections, viruses, and cancer. Aside from medicines, corals also provide up to US$375 billion worth of goods. Reefs also bring in money to local economies through tourism; diving and fishing tours, resorts, and other businesses utilize reef popularity, potentially bringing in several billion dollars[33].

Due to their high biological and economic value, the destruction and loss of the world's coral reefs can potentially have dire consequences. Not only will it wipe out diverse habitat, but it the loss of reefs can result in the loss of economic income from tourism and a decline in goods and services. Should coral reefs be completely destroyed, there is a potential for an increase in wave action on the coast resulting in higher erosion. Reefs also have value in being able to relay environmental information that is not yet interpreted in other ecosystems, such as climate

change. Because they are so sensitive, long term changes is temperature is fatal for a reef, and indicates to researchers that temperature change occurring past small fluctuations.

Future Outlook

Coral reefs are very sensitive, fragile organisms. They require a rather specific habitat to grow and are easily affected by changes in their environment. These changes can occur naturally, often caused by storms or changes in temperature, or via humans, such as changes brought about my run-off, other pollution, and recreational activities. Natural disturbances are often short in duration, and the coral can sometimes reestablish itself. But more often than not, damage is caused by humans.

Pollutants and river run-off deposit extra nutrients into the water, allowing for the degradation of quality and an increase in algae and phytoplankton. These organisms create competition, depriving the coral polyps of sunlight. Global warming is another factor – believed to be caused by the release of greenhouse gases, global warming is causing a gradual warm up of the ocean's surface water. This warm up is pushing corals temperature boundaries and is causing bleaching. This damage is appearing to be long lasting and permanent. The constant pressures wear the coral down to a point they cannot come back from.

Losing our reefs means the loss of not only the loss of a high diversity ecosystem, but also the loss of money, goods, and services. Many coastal towns near reefs rely on the tourism brought in to support their communities. Should the reefs be destroyed, these cities will have to find other means to support their economies. On a global scale, the loss of reefs could be the loss of potential medicines and cures for major diseases. Coral reefs are essential invaluable.

Overall, only ten percent of the Pacific's reefs are monitored for health. Because many reefs aren't easily accessed, most reefs that undergo review are near populated areas and thus more prone to deterioration. Data for reef health is also relatively new, which means there is no long-term data. Only local assessments on reefs were made until just a few decades ago[34]. Without long term data a true assessment of the decline and possible recovery of reefs is difficult to make, but an example is seen with Australia's Great Barrier Reef. It is thought that the Great Barrier Reef has lost half of its organisms within the past three decades. Two major components are an increase in cyclones, which smash against the fragile community breaking it to pieces, and the bleaching caused by increased sea temperatures. Australia contributes to this damage, with agricultural run-off and excessive tourism being a problem, but the problem also comes from international sources. Our choices here in America – such as high CO_2 emissions – affect the reef as well as it is an influence of climate change. Without worldwide corporation, ecosystems as fragile as coral reefs will always be in danger.

Conclusion

Climate change is often perceived very differently depending on where you are in the world and what you are experiencing. For some people, weather patterns are not unusual. For other people, the weather always seems to vary. In these cases, people may have a hard time understanding that other locations around the world are impacted very differently. In a situation where climate change is not perceived as a significant issue, it can be difficult for the general public to sympathize with other communities that are being affected. This has a wide range of effects, most notably is the effect on the public's view of environmental policies aimed at climate change. Countries that are not seeing significant climate changes or are in denial of the reality of

the changes they are seeing may consequently make policy decisions that can affect the whole world, including foreign ecosystems.

Decisions made here in America go on to affect other countries. Our carbon emissions, as well as other greenhouse gas emissions, contribute to climate change that affects the globe. Corals are amongst many species that are suffering the consequences, and in turn national and international economies and industries are being affected. Their decline is an indicator of two main aspects: the current rise in sea temperature in given areas, and the potential side effects of this change.

To prevent further changes and damage countries need to work together, protecting people and animals alike. The effort of a single nation will not be enough to counteract the contribution of the rest of the world. Our industries need to be proactive when it comes to emissions, both directly and indirectly, taking responsibility for the source of the materials and goods going into their services and products. There is no clear answer for what needs to be or should be done to slow climate change and its affects, but it is clear that nations need to work together if problems are going to be solved.

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